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(71) Applicant(s)
Airship Technologies Services Ltd
(Incorporated in the United Kingdom)
6th Floor Town Hall, St Paul's Square, BEDFORD, MK40 1SJ, United Kingdom

(72) Inventor(s)
Jeffrey Roger Munk

(74) Agent and/or Address for Service
J Y & G W Johnson
Kingsbourne House, 229-231 High Holborn, LONDON, WC1V 7DP, United Kingdom

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(56) Documents Cited
GB 2197276 A GB 2175651 A GB 0288272 A
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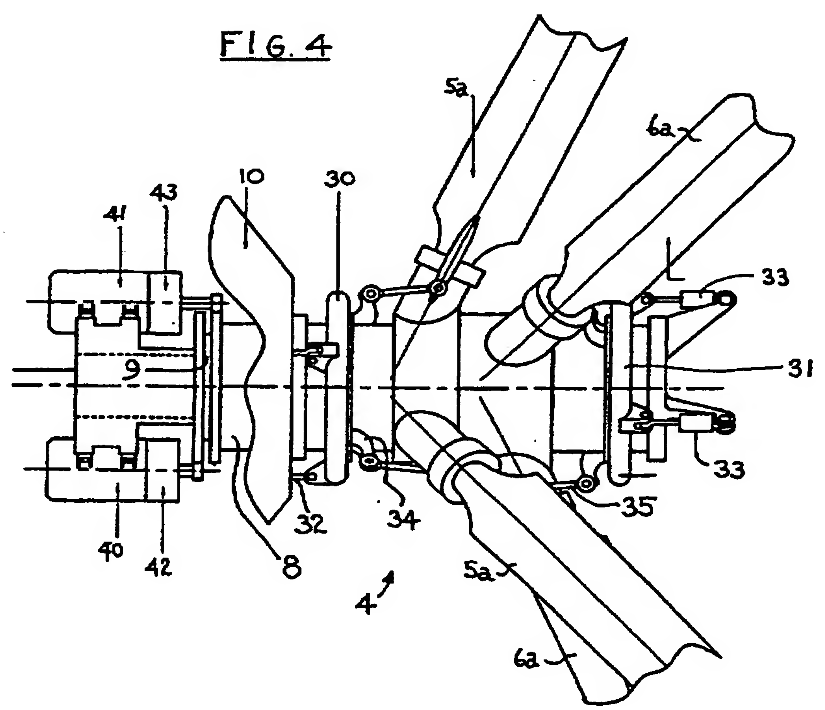
(54) Abstract Title
Propellers for airship propulsion and control

(57) A propulsion and control apparatus may be mounted via a cup-shaped structure 10 to the stern of an airship, and comprises first and second counter-rotating propellers having respective blades 5a, 6a, mounted at acute angles with respect to the axis of rotation of the propellers. The propellers are driven by respective motors 44, 41 via gearboxes 42, 43. The pitch of the blades 5a, 6a of each of the propellers may be controlled collectively or cyclically by means of respective swash plates 30, 31, operated by piston actuators 32, 33, to provide forward thrust, rearward thrust, or opposite thrusts on either sided of the airship, to achieve forward rearward or lateral control.

FIG. 4



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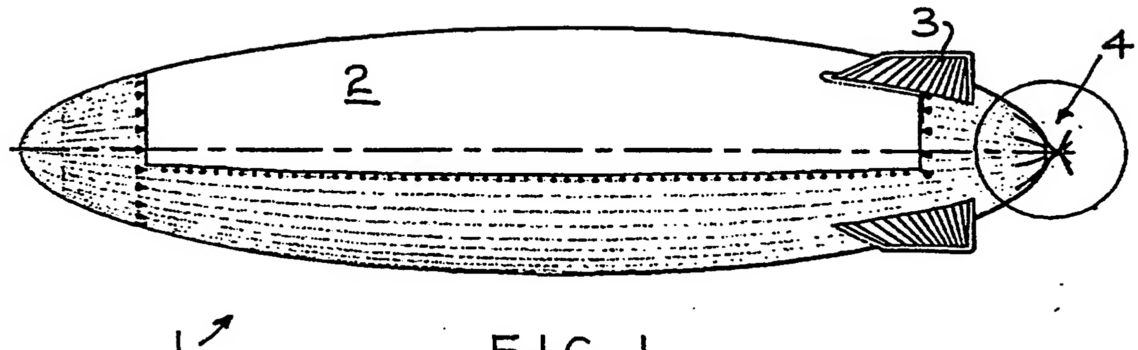


FIG. 1

FIG 2.

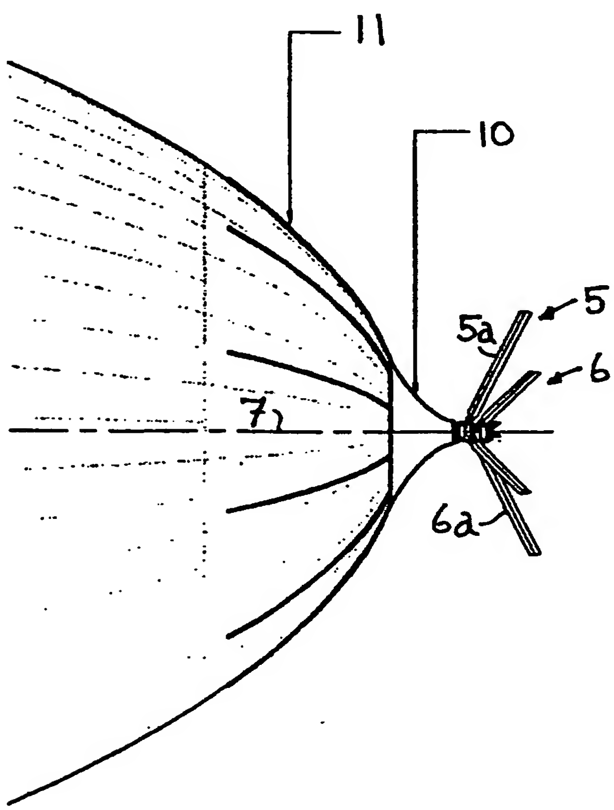
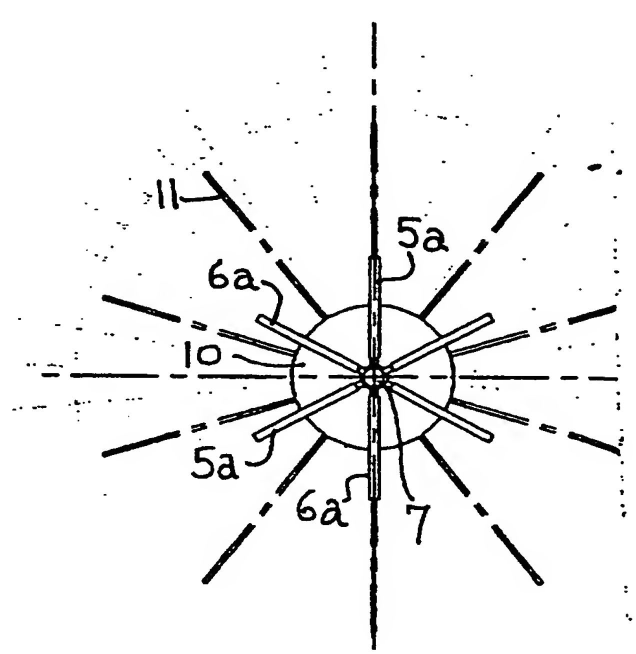


FIG. 3



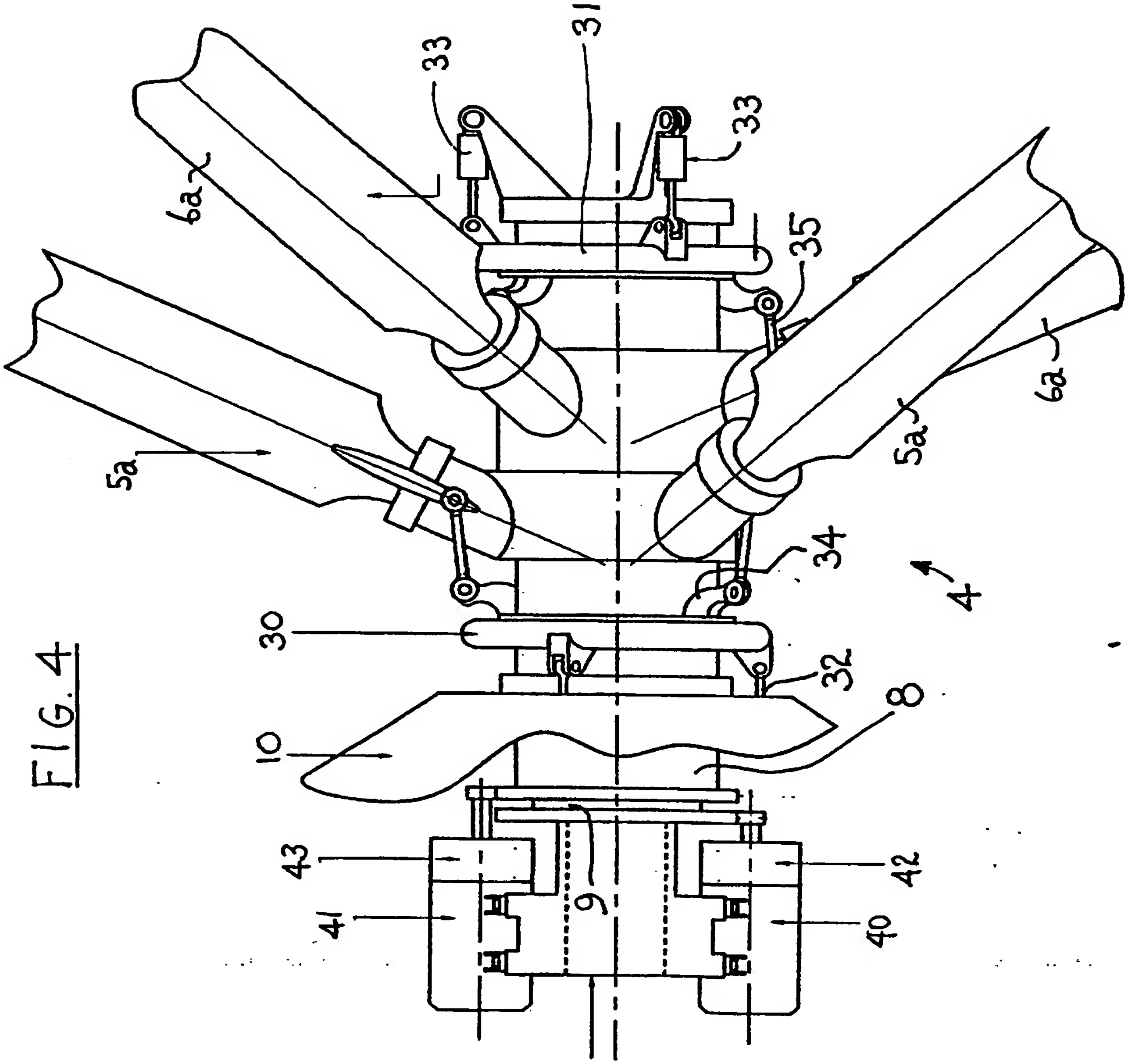


FIG. 4

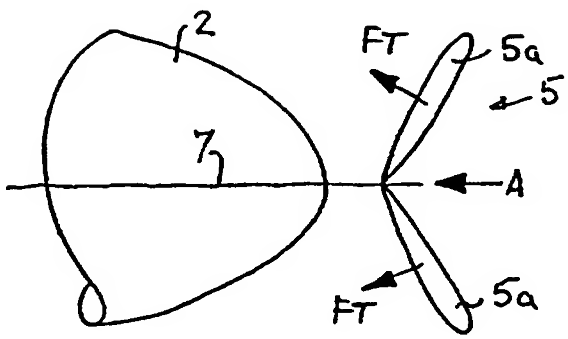


FIG. 5a

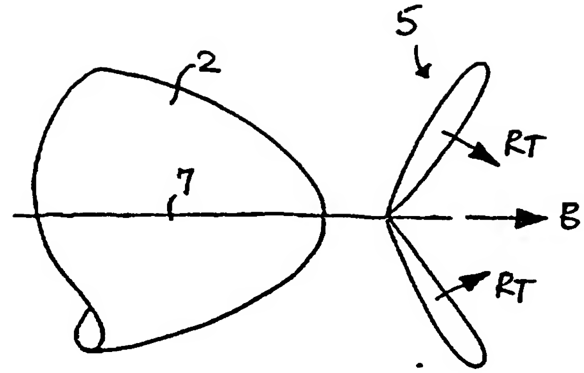


FIG. 5b

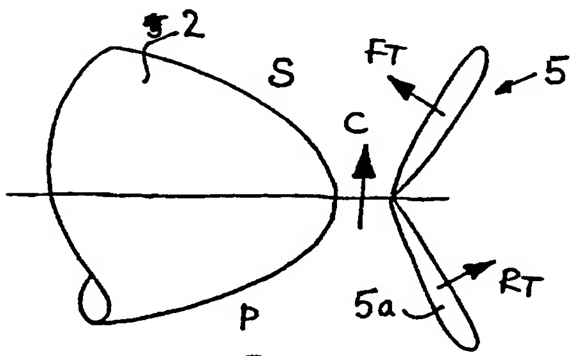


FIG. 5c

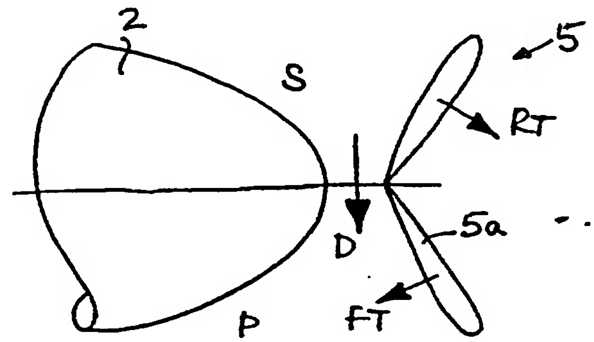


FIG. 5d

Duplex Coned Propellers for Airship Propulsion/Control

This invention relates to apparatus for controlling an airship and to an airship provided with such apparatus.

Many of the roles for which an airship is inherently well suited call for very long endurance. At low to moderate speeds, the energy efficiency of an airship is very high since little or no power is used to sustain flight. A means of propelling an airship which gives high propulsive efficiency therefore has a large effect on endurance at low to modest speeds.

For valid aerodynamic reasons the traditional means of stabilising an airship in flight has been by a set of fins set well aft on the hull of the airship. Control in pitch and lateral planes is then effected by equipping each fin with a movable control surface under pilot or automated control.

The airspeed regime where many useful roles exist or are foreseen is at the lower end of the spectrum of airship capability. Indeed some significant roles call for the airship to remain geostationary. However, at these low airspeeds, the fins and control surfaces have a much reduced effect, while the effect on the airship of perturbations due to atmospheric turbulence increases proportionately. In summary therefore the airship need is for a very high efficiency propulsion system which can also be used to enhance pitch and lateral plane control.

In GB-B-2,197,276 (the "Hillsdown patent"), the principle of propelling and controlling a low speed airship by means of a "coned tail rotor" was taught. The Hillsdown patent was particularly concerned with providing pitch and yaw control for ground handling of airships, i.e. the launching from, and mooring to, a fixed mooring mast. It was essential that the pitch and yaw forces be independent

of airspeed for this purpose. More recent considerations have shown this known invention could not have been successfully applied to airships operating at high altitude. In the rotor of the Hillsdown patent, the blades rotated at a fixed angle to the rotational axis which was significantly less than a right angle. Blade pitch could be varied cyclically and collectively to provide lateral control force and axial propulsive force, respectively.

The Hillsdown patent has certain deficiencies which render it unlikely that it will ever be reduced to practice. Its major deficiencies are:

- The benefits of engineering the blades to have high aspect ratio to give high efficiency in the propulsion mode was not taught.
- The means of achieving the stated aims failed to include any provision for system redundancy, where it is known that no civil aircraft of the required size could be approved by international regulatory bodies with such vital features as stability and control not duplicated.
- The patent describes no means of counteracting the torque of the rotor, which would impose a rolling force on the airship. For many roles, and in particular the unmanned stratospheric roles, the uncountered rolling moment would have serious effects.

An aim of the present invention is to provide improved control apparatus for an airship.

According to one aspect of the present invention there is provided control apparatus for an airship comprising first and second rotor means rotatable in opposite directions about a common axis, each rotor means including at least one blade means at an acute angle to the axis of rotation of the rotor means and mounted so that its pitch can be altered, first and second drive means for driving, respectively, said first and second rotor means, and first and second control means for controlling, respectively, the angle of pitch of the blade means of the

first and second rotor means during their rotation.

Control apparatus according to the invention provides a means of propelling and/or controlling the movement of an airship, with extremely high efficiency, by the use of a "coned propeller" arrangement. Such apparatus can be mounted on the extreme rearmost end of the lift gas containment envelope of the hull of an airship, which may be of the rigid or non-rigid type.

The first and second rotor means are suitably mounted on co-axial shafts which, in use, rotate in opposite directions.

Each of the rotor means is driven and controlled independently by its associated drive means and control means, where the only common item is that of the support structure providing the mounting on the hull.

The control means for each rotor means typically includes a swash plate for controlling the pitch of each of the blade means. In particular, the drive means and control means associated with each rotor means may be operated to control each of the blade means independently or together. For example, the blade means of a rotor means may have a collective blade pitch for controlling longitudinal propulsive force; or cyclic blade pitch in which the pitch of each blade means varies around the 360 degrees of its rotational azimuth. This cyclic pitch variation provides a resultant proportion of the longitudinal propulsion force at 90° to the rotational axis and in any azimuthal direction chosen and effected by the swash plates. Thus this lateral force provides pitch and yaw forces to stabilise and control the airship - even at zero airspeed.

Conveniently the drive means includes electric motor means. However other means of effecting power can be provided.

According to another aspect of the present invention, there is provided an airship having control apparatus according to said one aspect of the present invention mounted at the stern of the airship. The airship may have a rigid, semi-rigid or non-rigid hull to which the control apparatus is mounted.

An embodiment of the invention will now be described, by way of example only, with particular reference to the accompanying drawings, in which:

Figure 1 is a side elevation of an airship having stern-mounted control apparatus according to the present invention;

Figures 2 and 3 are a side view and an end view, respectively, of a detail on an enlarged scale of the airship shown in Figure 1;

Figure 4 is an enlarged view of part of the control apparatus of the airship; and

Figures 5a-5d diagrammatically illustrate the forces applied in use by a single "coned" propeller.

Figures 1-4 show the general arrangement of an airship 1 having a hull 2 with fins 3 towards its rear end. Control apparatus, generally designated 4, is mounted at the stern of the hull along the longitudinal axis of the airship.

The control apparatus include a so-called "duplex" propeller arrangement comprising two independent propellers, generally designated 5 and 6 and each comprising three blades 5a, 6a (although each propeller could have a different number of blades), which rotate in opposite directions about a common axis 7 on co-axial shafts 8 and 9. The provision of two propellers gives the necessary redundancy of operation deemed essential for certification.

The rotation of the propellers in opposite directions counteracts the rotational turning force created by the propellers on the airship. The swash plates 30, 31 are of conventional design, e.g. of the type generally used for controlling the pitch of helicopter blades as they rotate. As shown in Figure 4, the swash plates 30, 31 are actuated by piston actuators 32, 33 and control the blade pitch via links 34,35 forming part of the control means for each propeller. The propellers 6, 5 are driven independently by respective motors 40 and 41. The motors 40, 41 operate through gearboxes 42, 43, respectively, to drive the coaxial shafts 9 and 8, respectively.

The propeller blades 5a, 6a are movably mounted so as to have a controllable variable pitch. In particular the propeller blade pitch is controlled by separate swash plates 30, 31 which control the blade pitch during each rotation of the respective propellers 5, 6.

The control apparatus 4 can be attached to the stern of the hull of all main types of airship. For the rigid and semi rigid types, the rotor arrangement can easily by attached to the rigid structural elements of such airships. For non-rigid airships of the type shown in Figures 1 to 3, the rotor arrangement is secured to the gas-containing envelope of the hull. Indeed, the term "non-rigid" when applied to airships is a misnomer since a pressurised cylindrical structure possesses considerable rigidity. The hoop and longitudinal stresses generated by internal pressure in a thin skin structure give considerable rigidity even as a beam under bending loads. Moreover, very large point loads can be supported by such skins, provided these loads are applied in shear, i.e. in a line parallel (tangential) to the skin.

The preferred manner of mounting the control apparatus 4 on any airship is therefore to arrange for the local mounting structure to apply its loads to the pressurised fabric structure in shear. This is the means by

which the very large mooring loads in conventional airships are applied by the rigid "nose cone" - a cup shaped structure laced to the nose fabric. For a stratospheric airship, a cup shaped rigid structure 10 converts the propeller loads to a ring of points at the stern of the fabric envelope via battens 11. The attachment points are positioned where the envelope diameter is sufficiently large where hoop stresses provide sufficient rigidity. The rigid cup-shaped structure 10 can be of quite light scantlings by designing it to have a double curvature shape and by the fact that it is itself stabilised by the pressurised skin with which it is in contact.

Figures 5a-d illustrate the principles of the invention by indicating the forces which can be applied by a single propeller 5. The controlling apparatus of the present invention of course has two such propellers 5, 6 rotating in opposite directions, but the same principles apply for both propellers as for the single propeller arrangement described. The blades 5a are fixed at an acute angle to the axis 7 so that, on rotation, they sweep out a conical path, as opposed to the planar sweep of more conventional propeller blades. The advantage of this will be understood from a consideration of various modes of airship control, explained in simplified terms with reference to Figures 5a-d.

In Figure 5a, the pitch control mechanism has been used to adjust all the blades equally to what can be termed a forward collective pitch. The thrust from each rotating blade is indicated in Figure 5a by arrow FT. It will be seen that this produces a combined component of forward thrust in the direction of arrow A, urging the airship forwardly. It will be noted that there is no net lateral thrust produced in this control mode. The airship is thus propelled forwardly along the line of its longitudinal axis 7.

In Figure 5b, the situation is reversed. The pitch

control mechanism has been used to adjust all the blades equally to what can be termed a rearward collective pitch. The rearward thrust from each rotating blade is indicated in Figure 5b by arrow RT. The net result is a combined component of rearward thrust, arrow B, propelling the airship rearwardly along the line of its longitudinal axis 7.

In Figure 5c, the pitch control mechanism cyclically controls the pitch of the blades during each rotation of the propeller 5. Thus the pitch of each blade varies over the course of each revolution, with each blade varying in the same manner. Here, the blades are adjusted to have a forward pitch when on the starboard side S of the airship and a rearward pitch when on the port side P. The effect of this is that the rotor assembly produces a forward thrust, arrow FT, on the starboard side and a rearward thrust, arrow RT, on the port side. It will be seen that the net result is a lateral thrust in the direction of arrow C, urging the end of the airship to starboard. By the symmetry of the blades and the thrust thereby, there is no net thrust on the airship in Figure 5c along the line of its longitudinal axis 7.

In Figure 5d, the situation is the reverse of that depicted in Figure 5c. The pitch control mechanism cyclically controls the pitch of the blades during each revolution so that the blades have forward pitch when on the port side P and rearward pitch when on the starboard side S. The blades therefore produce forward thrust, arrow FT, on the port side P and rearward thrust on the starboard side S with a net result of a lateral thrust in the direction of arrow 1), urging the end of the airship to port. Again, from the blade symmetry, there is no net force urging the airship along the line of its longitudinal axis.

The duplex operation of the two propellers can be used in conjunction with each other so that the two propellers provide driving forces in the same direction when rotating in opposite directions.

CLAIMS

1. Control apparatus for an airship comprising first and second rotor means rotatable in opposite directions about a common axis, each rotor means including at least one blade means at an acute angle to the axis of rotation of the rotor means and mounted so that its pitch can be altered, first and second drive means for driving, respectively, said first and second rotor means, and first and second control means for controlling, respectively, the angle of pitch of the blade means of the first and second rotor means during their rotation.

2. Control apparatus according to claim 1, in which the rotor means are mounted on co-axial shafts which, in use, rotate in opposite directions.

3. Control apparatus according to claim 1 or 2, in which each of said control means includes a swash plate for controlling the angle of pitch of the blade means.

4. Control apparatus according to any one of claims 1 to 3, in which the drive means includes electric motor means.

5. Control means for an airship constructed and arranged substantially as herein described with reference to, and as illustrated in, the accompanying drawings.

6. An airship having control apparatus according to any one of the preceding claims mounted at the stern of the airship.

7. An airship according to claim 6, having a rigid, semi-rigid or non-rigid hull to which the control apparatus is mounted.

Application No: GB 9902875.5
Claims searched: 1-7

Examiner: C B VOSPER
Date of search: 3 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): B7G(GCHC,GCTR,GCTT); F1V(VAA)

Int Cl (Ed.6): B64B 1/00,1/06,1/24,1/30; B64C 11/00,11/30,11/46,11/48,19/00

Other: ONLINE: EPODOC,JAPIO,WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 2197276 A	AIRSHIP (whole document; control apparatus for airship comprising blades variable in pitch about acute axes by swash plate mechanism)	1-4,6,7
Y	GB 2175651 A	BASYA - (fig. 1; typical example of contra-rotating propellers)	1-4,6,7
Y	GB 0288272	KERMEKTCHIEW (fig. 3; contra-rotating rotors with acute angle blades)	1-4,6,7
Y	GB 0234305	BOVEY (whole document; contra-rotating rotors having acute angle blades)	1-4,6,7
Y	EP 0363997 A2	UNITED (col.10; claim 1; contra-rotating rotors with variable pitch blades)	1-4,6,7
Y	US 4204656	DEWITT (col. 2, lines 41-43,48-49)	4

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Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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